atf

Research & innovation for a competitive and sustainable animal production sector in Europe

Recommended priorities for support under Horizon 2020 in the 2016/2017 work programme

1st Addendum to the Animal Task Force White Paper

November 2014

General Introduction

Animal production contributes substantially to the European economy (€130bn annually), and supports food security, development of rural areas and ecosystem services. The sector encompasses both farmed animals in agriculture (meat, dairy, and egg production and also skin, fur, and wool), in societal services (sports, recreation, landscape and ecosystem services), as well as in aquaculture (fish and other seafood). As part of a circular bio-based economy in Europe, the animal production sector has major opportunities to contribute to a more sustainable, climate smart and competitive Europe and to ensure responsible European animal production in a changing global world. For the optimal use of produced biomass, animal production is essential. Research and innovation has contributed greatly to making Europe's livestock and aquaculture sector as competitive, balanced and efficient as it is today. Continued support is needed for research and innovation in the livestock and aquaculture sectors if the new challenges are to be met. These challenges include the supply of safe and healthy high quality food, reducing environmental impact, making better use of resources, respecting animal integrity, meeting needs of consumers and contributing to a viable economy in ways that are appreciated by society.

In April 2013, the **Animal Task Force** (ATF) presented a White Paper identifying key areas in the livestock and aquaculture sectors that require European research support. This Addendum to the ATF White Paper is an updated view, and identifies priority research topics from the key areas identified in 2013. This update has been developed by the ATF members and is inspired by the Strategic Research Agendas of several ETPs and other sector organisations; as well as that of the FACCE-JPI, Global Agenda for Sustainable Livestock, Global Research Alliance on agricultural greenhouse gases, FAO, and the SCAR working group on Sustainable Animal Production. An additional consultative meeting with farmers and industry organisations was organised in April 2014. All these new views and insights have been incorporated in a review and update of the priority topics as presented in this first Addendum to the ATF White Paper.

The Animal Task Force

The Animal Task Force was established in 2011 as a European Public-Private Platform of the main research, farmer & industry organisations working together to foster knowledge development and innovations to secure a sustainable and competitive animal production sector in Europe. The scope of work covers the whole animal production chain.

For more information please visit w**ww.animaltaskforce.eu**.

The key areas for research and innovation in the animal production sector, identified in the ATF White Paper are:

- **Resource efficiency** – using limited resources in a sustainable manner by robust and efficient animals; more efficient feed chains that incorporate animal health and welfare; making better use of livestock, aquaculture and fishery by-products and alternative feed resources; and the use of precision livestock farming and aquaculture.
- **Responsible livestock farming systems** – minimise the environmental impact of animal production while improving animal health and welfare; increase protein and energy autonomy in Europe; improve productive grassland based livestock production; improve sustainable use of water resources; and create climate smart, robust and resilient animal production systems.

- **Healthy livestock and people** – prevention and control of disease by integrated management of animal health and tools; better understanding the microbiomes; restrictive use of antibiotics; improve product quality; and increase food and feed safety, and limit the transfer of zoonotic diseases to humans.
- **Knowledge exchange towards innovation** – cooperation and knowledge exchange with producers towards innovation; implementation of animal welfare management and 'omics' tools.

Within this spectrum, 12 priority-topics have been identified in the ATF White Paper in 2013 (Figure 1). All these identified key-areas and priority-topics are still highly relevant since the ATF White Paper was prepared with a perspective for the full period of the Horizon 2020 period up to 2020. Several of the topics have been reflected in the 2014/2015 Horizon 2020 work programme.

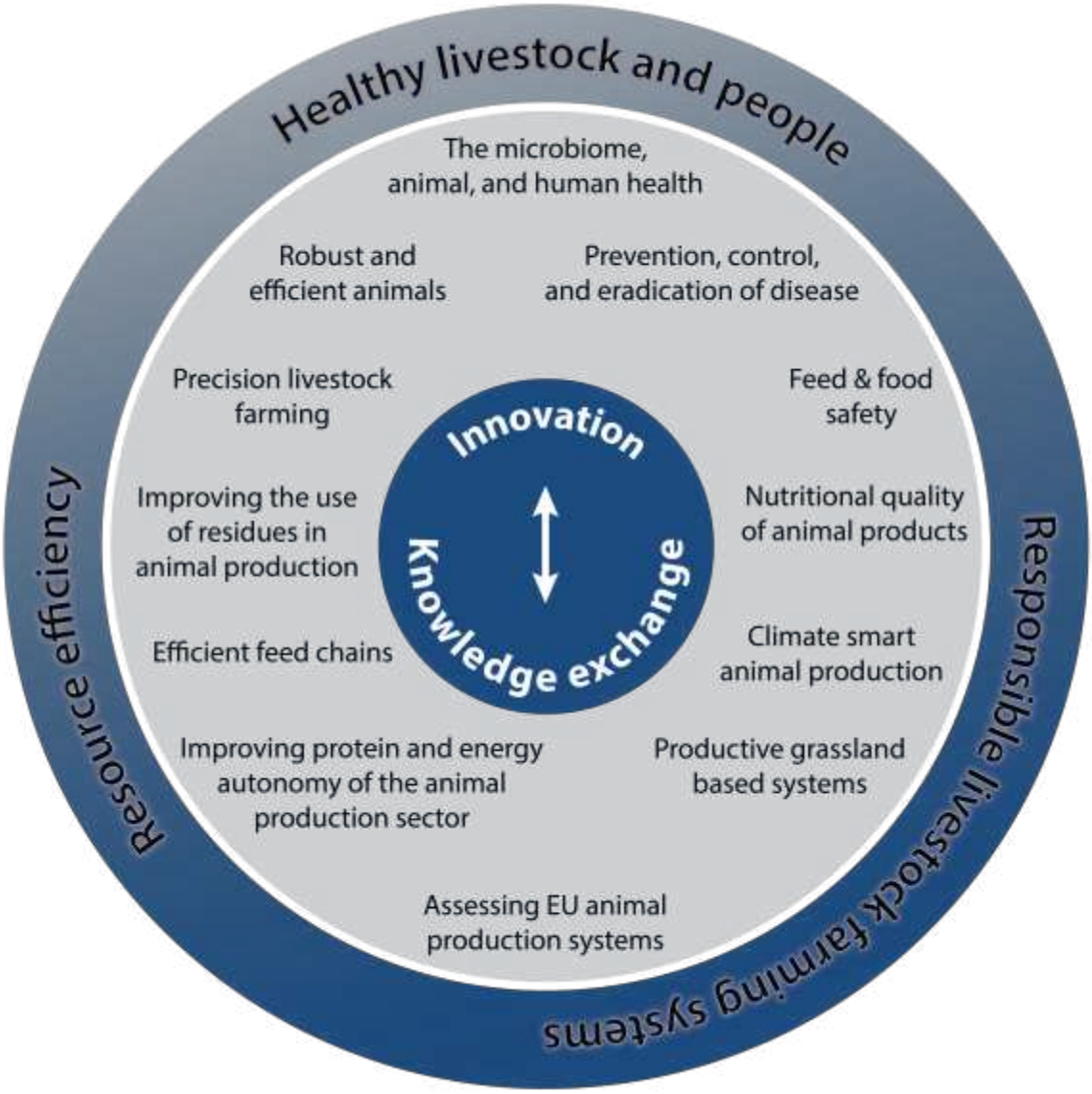

Figure 1. Key areas and priority-topics for science and innovation that ATF suggest to support the livestock production sector. The circle summarises the ATF White Paper.

In this 1st Addendum of the ATF White Paper, we now focus on priorities that merit support in the 2016/2017 work programme of Horizon 2020. We do not introduce any new topics, but we highlight and specify priorities that we recommend to be supported in the next calls. We see these as essential for the further development of a competitive and sustainable animal production sector in Europe. In this recommendation (Figure 2), we have excluded the priority-topics identified in the ATF White Paper that have already been included in the Horizon 2020 call 2014/2015 and other recent European research programmes.

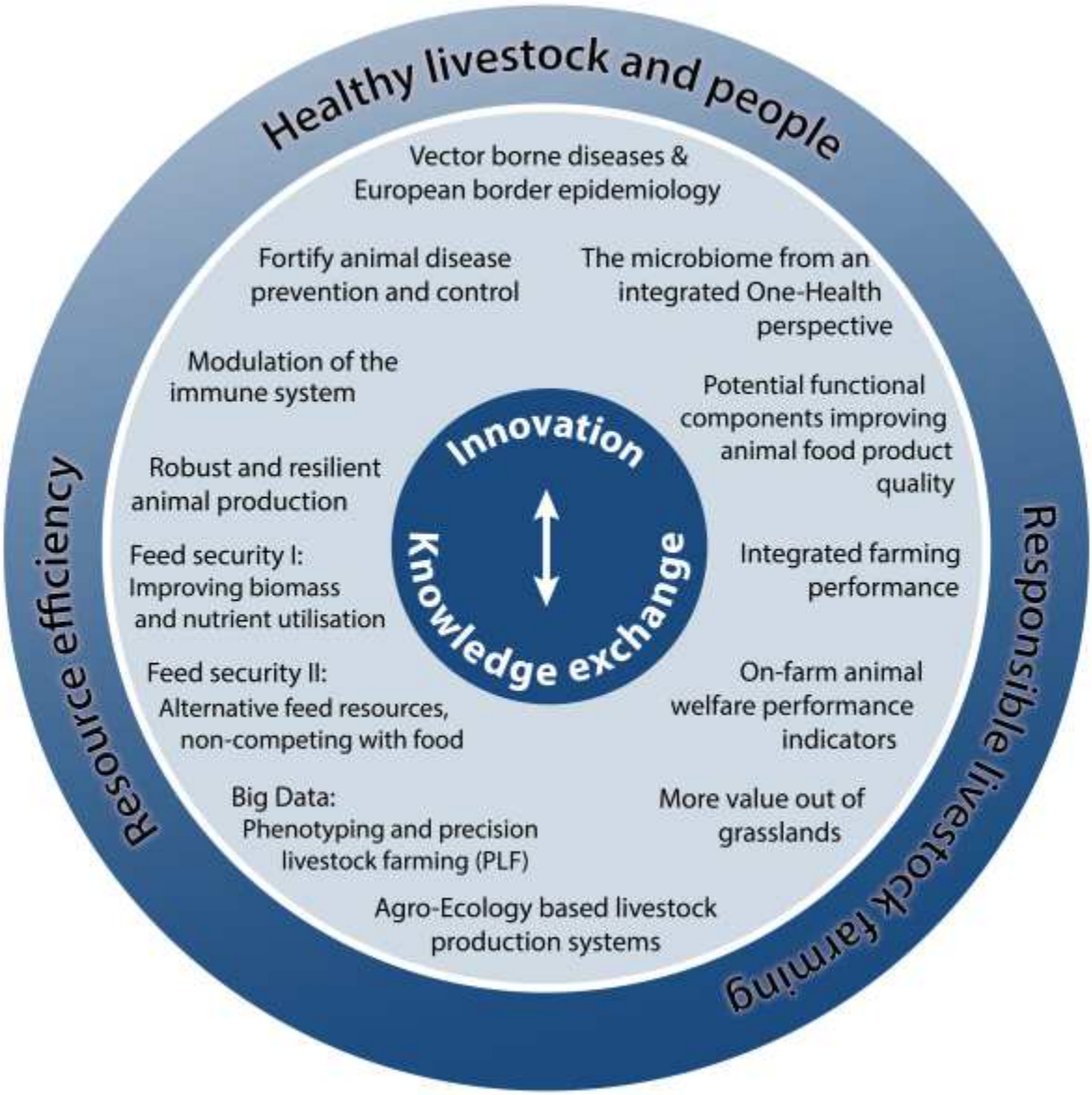

Figure 2. Key areas and specified priorities that ATF suggest to support the livestock production sector by science and innovation for the 2016/2017 work programme.

The wheels in figures 1 and 2 show the priorities that ATF suggests for research. Figure 2 emphasises the priority topics that we identify for action in the 2016/2017 work programme. The wheels are built up from the three key areas of societal challenges for the animal production sector (outer circle) and that should lead to the exchange of

knowledge and innovation as focal point (inner circle). In between are the priorities for knowledge development (research). These are the priority-topics described in the ATF White Paper and this Addendum. The outer circle shows the link with society, the inner circle the link with practice; resulting in research priorities linking the societal realm with the development (farming) practices that makes the sector more competitive and sustainable. The middle circle is clearly the domain of Horizon 2020; the inner circle of the European Innovation Partnership for Agriculture Productivity and Sustainability.

In the process of identifying priorities for next action, 43 topics have been condensed to 13 topics **all of which we consider to be important for action** in the next round of Horizon 2020. ATF members and industry organisations with the potential of becoming a member have ranked these 13 priorities that are presented in the Addendum in 3 categories for relevance. For ease of presentation we list them below using a simple star system to emphasise relative priorities.
Thus:

★ indicates an important topic;
★★ indicates a very important topic;
★★★ indicates a high important topic.

Resource efficiency	
Priority A: Feed security I: Improving biomass and nutrient utilisation	★★★
Priority B: Feed security II: Alternative feed resources, non-competing with food	★★
Priority C: Robust and resilient animal production	★★★
Priority D: Big Data; Phenotyping and precision livestock farming (PLF)	★★★
Responsible livestock farming systems	
Priority E: More value out of grasslands	★
Priority F: On farm animal welfare performance indicators	★★
Priority G: Integrated farming performance	★★
Priority H: Agro-Ecology based livestock production systems	★
Healthy livestock and people	
Priority I: Fortify animal disease prevention and control	★★★
Priority J: The microbiome from an integrated One-Health perspective	★★
Priority K: Modulation of the immune system	★
Priority L: Vector borne diseases & European border epidemiology	★★
Priority M: Potential functional components improving animal food product quality	★

Note: This Addendum only presents the priorities that we have specified in more detail for the 2016/2017 work programme. For the complete description of the key areas with priority-topics, please see the ATF White Paper (2013).

Resource efficiency

The main challenge for the world is feeding 9 billion people within the carrying capacity of Planet Earth. The livestock sector is a valuable component of the bio-economy (in food and non-food functions). In next decades, on the one hand we expect an increased demand for animal products, because of growth of the global human population, growing incomes and a shift in consumer behaviour worldwide, especially in the upcoming economies. On the other hand we face land scarcity, increasing greenhouse gas (GHG) emissions and limited resources, and it is to be expected that the availability of resources outside Europe for the European market (either as base (feed) or end products) will decrease or come available only at a much higher cost. This is a double challenge: the *efficiency* of the *use* of resources (e.g. energy, N, P, water, manure) must increase while at the same time improvements in the *way we produce and use* these resources must be made, so that the environmental footprints are reduced and the requirements for food production (e.g. health, welfare, social acceptance) are fulfilled. The importance of a good European animal knowledge sector, and of ensuring the European animal production capacity for both the current and the future generation gain recognition.

To find ways to enhance food security in a sustainable way, we will need to pay greater attention to the efficient use of all associated resources. We should minimise the need for resources, prevent avoidable losses ('wastes') and emissions, re-use unavoidable losses as feed wherever possible, use manure as a valuable residual. Throughout, we must search for the optimal systems for the various species, taking account of region-specific circumstances. This requires attention and improvements to the animal *as* a system, the animal *in* a system, and the system itself. Closing the nutrient cycles and re-use of valuable resources are central in this issue.

Animal production chains with increased resource efficiency enable a shift towards more sustainable intensification of food production and competitiveness of EU animal production chains. Socio-economic advantages are food security, sustainability, a reduction of climate change effects and realising a bio-economy. There will be improvements in biological and economic efficiency with reduced waste and emissions. Optimal solutions will recognise potential trade-offs between efficiency gains and health and welfare, or other important disadvantages and losses. Identifying 'win-wins', or at least clarifying key trade-offs will enable better decision-making.

For the 2016/2017 work programme of Horizon 2020 we recommend four main priorities to address the "Resource efficiency" issues:

A: Feed security I: Improving biomass and nutrient utilisation
B: Feed security II: Alternative feed resources, non-competing with food
C: Robust and resilient animal production
D: Big Data; Phenotyping and precision livestock farming

Priority A
Feed security I: Improving biomass and nutrient utilisation

Livestock and aquaculture production is highly relevant in the bio-economy to ensure a maximum (full) use of biomass produced in a circular economy. Sustainable intensification requires optimal utilisation of biomass components across industries and production of more and better animal products with fewer resources and less waste. This includes the reuse of residues from bio-industries (where these have potential to yield valuable nutrients and energy) in order to optimise their utilisation across the value chain. In this way the exploitation of various raw biomaterials resources can be the driving force to develop new feeds. The goal is to improve existing and/or develop novel products, processes and logistical networks that will improve resource use for livestock production synergistically with improved use of raw and processed materials in other industries.

There should be focus on the need to secure a sustainable protein supply for feeding animals (and thereby for human feeding). In addition, given the growing competition for energy feedstock (e.g. bio-fuels), there is a growing need to find alternative sources of feed energy for livestock. This will allow the farming sector to continue fulfilling its primary mission: the production of food.

Special attention should be given to:

- Development of innovative solutions and novel processes for more efficient use of raw materials (across industries), and development and/or optimisation of techniques to separate the protein fraction of feedstuffs or side streams to finer target the needs in diets for animals.
- Exploring and developing alternative sources of feed energy including alternatives to fish oil and fish meal. The feed sector should identify those available feedstock resources that may be explored "more and better". This includes knowing better how to optimise the feed use of newly available resources such as co-products from non-food industry.
- Development of detoxification techniques to allow safe use of these new resources in animal feed, consequently reducing the pressure on agricultural resources since novel feed resources may contain anti-nutrient factors (for example mycotoxins) or contaminants at low levels.
- Development of innovative, cheap technologies to concentrate these products to ensure optimal valorisation. Many co-products or residues of the agro-industry have a very low dry matter content, which poses immense problems towards transport, shelf life and feasibility for their use as animal feed.
- Development of new systems to produce organisms with manure and other biomass wastes. The new organisms include algae, worms, insects, and microbes to recuperate nutrients for the feed chain, or to extract bioactive-compounds for the biobased industry.
- Development of practical models, for instance based on consequential LCA, to determine the role of livestock and (shell)fish in use of resources and the trade-offs amongst environment-socio-economic impacts when decisions are made concerning the use of by-products and alternative resources.
- Create new feed quality assessment systems to overcome the limitations of current feeding systems that are based on dogmatic "feed values" and "nutritional requirements", ignoring the fact that individual animals can dynamically adapt and respond to nutrient supplies. There is a need and willingness to develop an

innovative and modern European standard for animal nutrition management and to harmonise systems.

- Develop guidelines for processes and policies for improved resource use that anticipate social concerns. Whilst there is widespread understanding of the need to improve the efficiency or re-capture of secondary ('waste') products in the food chain, some practices may not appeal to society at large as being acceptable. Furthermore, the use of by-products of animal origin as feed for another species will importantly contribute to sustainable resource use, but requires optimal traceability to ensure consumer acceptability of the final food products (e.g., ruminant by-products are used for monogastric feed, and not for ruminant feeds). As this is this currently not embedded in law for livestock feeds (but it is for aquaculture feed), research and appropriate technologies are required to provide the required scientific proof and underpin policy preparation. The social acceptability of current and prospective novel options for the management of wastes to improve overall resource use efficiency need to be assessed ahead of implementation.

Priority B
Feed security II: Alternative feed resources, non-competing with food

European livestock and aquaculture production is strongly dependent on protein rich feed resources that are imported and/or that can be used for human consumption directly. In the long run, that may not be sustainable. Therefore, the use of (alternative) protein rich raw materials produced or available in Europe is foreseen.

Improvement of protein self-sufficiency of European terrestrial livestock could be realised through locally produced proteins of various kinds including soybeans (grain or silage), other legumes, grazed pasture, grains, processed forages, protein sources or co-products or residues from the agro-industry and extracted protein/amino acids. In order to develop sustainable and competitive protein sources for European terrestrial livestock production, while not compromising quality and health aspects, the main research and innovation needs are:

- EU protein sources for animal feed products in a whole value chain approach from production of raw material, through processing and up to production of animal feed products.
- Digestibility, nutritional value, health and food safety aspects of novel EU protein sources.
- Assessment of ecological and socio-economic sustainability, nutritional value, health and food safety aspects of EU protein sources.
- Facilitation of multi-stakeholder interactions to support market uptake.

Improvement of protein self-sufficiency of European aquaculture could be realised by alternatives for fish based aqua feeds. Proof of concept studies have already established that fish can be produced without or with very little (according to species) wild fish products, with a fish:fish ratio <1 when using resources that can be directly used by humans (glutens and other protein concentrates in particular). There is a need to find novel ways to replace some of these plant products using alternative resources such as insect products, algae or animal protein to limit competition between food and feed. There is a need to develop *in vivo* models for studies on health-promoting diets with functional ingredients and lipids that work in synergy to enhance the ability of fish to cope with stressful situations such as inflammation induced by alternative feed resources. In parallel to the changes in the composition of the food, progress can be expected by genetic selection of high performing fish using these new protein sources. Alternative resources in recirculated aquaculture systems should also be included.

Priority C
Robust and resilient animal production

Animal production systems and chains are needed that are more robust and resilient to large variations in feed supply from their owners' land, but also from purchased feed and co-products. These systems might make use of common breeds as well as local breeds. Application of balanced breeding programmes is advised, and the genetic variation within aquaculture breeds could also be used more effectively. Solutions are needed at different scales (farm, regional, EU) and should integrate strategies of adaptation to local crop and forage production, integrated herd management (production, health, welfare, emissions) and alternative options for manure management.

Enhancing animals' ability to resist and overcome (emerging) diseases, nutritional or environmental challenges will help them to stay healthy and well adapted to their living conditions, i.e. increase their robustness. This also implies well-adapted husbandry. From a societal angle, better alignment of welfare of animals and public perception is needed. Developing competitive systems that fully meet animal welfare requirements will help the sector show corporate responsibility, improve transparency and disseminate clear, relevant and understandable communication to society at large Firstly, to accelerate progress on these issues a particularly important goal is to develop improved tools to speed up the identification and introduction of important genomic and phenotypic characteristics of robustness. This will lead to improved welfare, resistance to emerging diseases and adaptation to climate change. Progress here will be a key factor in improving these traits simultaneous with other traits important for a competitive and sustainable livestock sector. Secondly, optimising the animals' early living environment and facilitating their ability to develop appropriate physiological, immunological and behavioural responses to social and other challenges will support robustness and the ability to cope. The farmers' management skills in relation to how they run their business as well as how they handle their animals plays a crucial role. Innovative monitoring and IT techniques can provide valuable tools to support effective animal herd management. Priority actions are:

- New improved breeding programmes for efficient and robust animals e.g. through development of tools to implement genetic evaluations from detailed phenotyping (including data from metabolomics and metagenomics analysis) on a limited number of specialised research herds into population genetic/genomic evaluations. This will require new and widely agreed insights and processes for the acquisition, collation and analysis of phenotypic data at different levels of detail. Associated actions to achieve this are:
    - Appraise the use of combinations of new sensor methodologies and more traditional approaches to access biomarkers for health and welfare. Development of processes for the recording of diseases, such as metabolic and nutritional disorders, reproductive problems, infectious diseases (mammary and foot diseases, diseases of the respiratory and digestive tract), and immune deficiencies.
    - Identification and specification of ways to standardise recordings across laboratories for effective data sharing when large-scale recording of detailed phenotypes is required.
- Understanding of key pathophysiological factors that increase health and welfare of animals in all parts of the life cycle or that hamper robustness. The latter activities will focus on critical transition periods and on the development of new strategies to

cope with these transitions, including the setting up of favourable epigenetics marks.

- In light of changing climatic patterns, with periods of more extreme events, and the heightened likelihoods of novel disease challenges (partly linked to climatic changes) there is a need to develop technical solutions for managing animal production systems under periods of high or low ambient temperatures, drought or heavy rainfall and emerging diseases. Attention is needed for both livestock (confinement and outdoor systems)and aquaculture. This requires a system for integration of breeding programmes, feeding regimes, farm/aquaculture techniques and veterinary care. The goal is to deliver practical guidelines for the design of systems and disease management protocols that will reduce the risks to livestock and livestock businesses of these heightened challenges. The practical guidelines should build on the results of the FP7 AnimalChange project.
- The robustness/resilience of livestock, and (shell)fish can be enhanced by exploiting its adaptive capacity. Studies have shown that stressful conditions during early life enhance the flexibility of the animals at later life stages (so-called "early programming" effects). A better understanding of the mechanisms underlying these effects may provide tools for producing robust/resilient animals and animal production systems. This is of particular interest in aquaculture, where early programming can help and provide animals that cope better with vegetarian feed and maintain the capacity to produce the desired n-3 fatty acids.

Priority D
Big Data; Phenotyping and precision livestock farming (PLF)

To meet policy goals for more efficient use of resources combined with emphasis on better animal health and welfare, practical options should be sought for combining genetic, genomic, metabolomic and phenotypic information to gain a better understanding of biological processes and to improve selection decisions for livestock by exploiting technological gains in these areas. This includes the identification and implementation of welfare indicators that are animal-based and selection for breeds that are well adapted to the specific livestock system (improved 'adaptive capacity' and 'disease resistance'). The combined use of genetic, genomic, metabolomic and phenotypic information is innovative. The goal is to provide a toolbox of deliverable products and/or processes to allow these potential advantages to be realised. This will build on concepts that are developed through the 2014 call SFS1A, thereby helping to develop a coherent programme of work.

New techniques for deeper phenotyping, including metabolic profiling, sensor technology and remote sensing are required. Precision Livestock Farming (PLF) on the one hand, and the genomic revolution ('omics tools and data') on the other hand, are key elements for successful implementation in the breeding sector. However, these technological developments are so far evolving in two separate worlds. Breaking this fragmentation by bridging knowledge and relevant actors will renew predictive biology approaches, generate new knowledge and is crucial for advancing together smarter farming and competitive breeding. A main goal is to develop and share innovative pipelines dedicated to high-throughput delivery of big data generation and analysis. Computer databases and data management and analysis facilities are necessary tools for handling the huge amount of data relevant to livestock and fish production, and for simplifying the localisation, the extraction and the analyses of relevant information. Such research databases will be shared through common projects and will include original data (genomic data, precision livestock farming data) and classical performance data (dairy production, body weights, health proxies, real health parameters etc.). Innovative scalable management tools will facilitate the acquisition, the storage, the access and the links to other public databases such as climate databases. Scalable computer facilities will make available data mining tools capable of integrating and analysing huge amounts of diverse types of data from different sources. In this way, such shared data infrastructures are essential components of systems biology methodologies (heterogeneous data integration and modelling), serving as proof-of-concept projects to explore new polymorphic combinations of genomics, epigenomics and metagenomics and to better predict the adaptation of animals and their production systems. Such novel databases can act as models for shared infrastructures to combine new sources of data as they become available in the future.

Development of automated data sampling and analysis from the production chain including appropriate indicator traits and sensor data is key requirement for further optimisation of efficiency, health and welfare at animal and herd level. The opportunities to automatically collect data on a large scale have created major challenges for Big Data analysis.

The development of predictive biology approaches in PLF requires the development of mathematical decision support modelling (e.g. data mining and artificial intelligence), (wireless) sensor technology (including remote sensing and telemetrics) ICT-

infrastructure (web based, databases), standardisation (e.g. RFID) and user-centric design methods to evaluate the benefits of combining data from different origins (biological, behavioural) and to improve the quality of the diagnosis and support. Research will focus on biological models and decision support tools. Data from different systems/sensors needs to be made available for farmers and third party software developers. This will enable development of decision support software for integrated farm management independent of hardware vendors and allow combining data from multiple single signal systems. The goals are to create systems for the collection, collation and sharing of relevant data and the creation of protocols for the use of such data in software development for smarter farming systems.

Several barriers to sharing of (open) data have to be removed. Farmers are reluctant to give access to their farm management and sensor data, including data on variation within soils, crops and livestock. They want to be in control of who can see and use the big data. Only a few farmers see that this big data can be used as a sign of Good Agricultural Practices and can become a licence to produce. Another challenge is that there is a need for access to good quality public data. New business models for sharing of data and open data sources should be developed to bring PLF to the next level and benefit from Big Data. Recognition of ownership of data is crucial. Also portals to facilitate exchange of data are a prerequisite.

Responsible livestock farming

Livestock farming systems generate valuable and desirable products for the human diet including some from resources that cannot otherwise be converted into food (grass-based systems, agro-industrial side streams). They also support the development of rural communities (especially in more remote areas), contribute to management of ecosystems and increase biodiversity and are in growing demand, globally, to meet changing dietary preferences for ever more affluent communities.

However, the past also showed drawbacks of continuous growth of the animal sector such as challenges to the environment (through gaseous emissions, water and soil pollution and ecosystem damage), human health (through zoonotic diseases) and for the welfare of animals within the systems. This will be part of the continuous discussion between the livestock sector and societal needs. Hence future and present farming systems need to be (re)designed, discussed with society, integrated in a regional and economic context and give social and ethical value to the people working with and in these systems and value to the individual animals living in these systems.

For the 2016/17 work programme of Horizon 2020 we recommend four main priorities to address the "Responsible livestock farming" issues:

E: More value out of grasslands
F: On-farm animal welfare performance indicators
G: Integrated farming performance
H: Agro-Ecology based livestock production systems

Priority E
More value out of grasslands

Grasslands cover around 40% of the EU agricultural area. Permanent pastures account for 57 million hectares, of which 16.9 million are rangeland including shrubs and bushes. Temporary grasslands represent another 10 million ha. European grassland area has been significantly reduced during the last thirty years (by 15 Mha). However, ruminant production systems using grassland and grazing deliver high value protein for the human population from resources that cannot otherwise be used for that purpose. Such systems have also mixed benefits with regards to the delivery of environmental goods (soil quality, closing nutrient cycles, Greenhouse Gas (GHG) balance including carbon sequestration, biodiversity). Additionally, grassland-based systems promote a clean, animal welfare-friendly image for ruminant production, and open landscapes with grazing ruminants are highly appreciated by the public. Increased attention should be given to maximising the 'ruminant advantage' by developing grassland-based systems, including improved crop rotational systems, which are productive, more environmentally acceptable and addressing the trade-offs between competing goals. Instability of the prices of animal products and the projected price increase of non-renewable energy and mineral fertilizers will further reinforce the necessity to develop innovative systems with a high efficiency of input utilisation. Finally new policies may favour the development of grassland based systems: climate change mitigation policies could support the maintenance of grassland for carbon sequestration, cross-compliance requires that farmers comply with a set of Good Agricultural and Environmental practices including the obligation to maintain the proportion of permanent grassland in the Agricultural Area. Farmers must also respect the Habitat, Bird and Nitrate Directives. Rural development expenditures can be a tool for supporting grassland-based systems and disadvantaged areas payments contribute significantly to the income of livestock farmers in those areas.

An integrative approach for grassland management that is cost effective, environmentally sound and manageable is essential in both the context of the development of large scale dairy enterprises with highly productive healthy animals, that benefit from high welfare standards, and in less favoured areas where extensive grasslands and low producing ruminants are a key issue for biodiversity, recreation and landscape maintenance. In the recent past, the MultiSward project provided and disseminated an EU-wide and multifunctional oriented overview of grassland-based ruminant production systems. In particular MultiSward clearly showed that multispecies swards with legumes can contribute to more sustainable ruminant production systems; that performance of grassland-based systems requires well-suited breeds; and that developing appropriate grazing management strategies can increase grassland biodiversity in marginal land. Despite these significant progresses, some key questions remain to be solved. A programme of research is required to:

- Evaluate integrated approaches that combine improved management skills, innovative management systems and techniques, feeding and nutrition practices and genetic improvement through selection for robust adapted breeds or genotypes in different systems of production.
- Identify innovative grazing systems that are technically and socially feasible, efficient and economically viable for large-, medium- and small-scale farming systems, for extensive and intensive farming systems, for full time grazing and situations where grazing will only represent a moderate part of the annual diet of the herds.

- Increase the yield of grasslands through a smart combination of extending the grass growing and grazing season, reducing grazing losses, improved grassland composition and grassland use, efficient use of fertilisation and ICT technology at farm level.
- Exploit adaptive capacity to optimise the most profitable genotype or breed, which is a key factor to return the highest profit per unit of the most limiting input and to limit harmful environmental emissions. This means selecting animals with a better equilibrium between production and robustness for intensive systems and to exploit the adaptive capacity of herbivores to make better use of grasslands in marginal areas. This requires a better understanding of adaptive capacity (genetics, early life experience, ability to cope with environmental fluctuations). Also, it is necessary to manage this adaptive capacity, i.e. matching animals to environments, and getting the right blend of animals with different capacities in a herd (i.e., adaptive capacity of a farm). Management should be tailored to best exploit adaptive capacity.
- Development and testing of new plant production systems and new multispecies grasslands having fewer requirements for water and higher resilience to drought is required, as climate change will result in more extreme climatic conditions with longer periods of extreme ambient temperatures and more variation in climate during and within the season thus requiring adaptation of forage production (including genetics).
- Identify ways of increasing nitrogen and phosphorus use efficiency and minimise water and energy use.
- Identify key traits that relate grassland management with biodiversity and carbon footprint, especially in permanent grasslands. Strategies to combine maintenance of biodiversity and low carbon footprint with farming profitability must be identified.
- Improvement of the existing decision support systems. Those systems mainly reflect the state-of-the-art, and the limitations of the current knowledge. New research is required to improve their precision and robustness. Particular attention should be given to gradients of situations in terms of acreage of grassland within territories and intensity of use.
- Identify fail factors that limit the use of the identified techniques/systems by farmers and summarise how to address these factors.

Priority F
On-farm animal welfare performance indicators

The position of animal welfare in the debate on sustainable production can be viewed from three vantage points/objectives. First, from an animal and animal husbandry point of view: we must keep our animals in the best way possible to meet their welfare requirements while avoiding negative effects on e.g. farmer income or environmental impact. Secondly, from the farmer point of view the need to achieve economic sustainability is interacting with animal welfare. Thirdly, from a societal angle it is important to help the sector show corporate responsibility, improve transparency and disseminate clear, relevant and understandable communication to the society at large, and overcome the hurdles that cause discrepancy between animal welfare and perception of animal welfare. The latter requires involvement and responsibility of the wider actors in society than farming sector alone.

The goal is to develop innovative sustainable animal production systems in which there is a sound balance between animal welfare and other demands from various actor perspectives (e.g. increased efficiency, economic sustainability, food security, mitigation of global warming).
Animal-based indicators for animal welfare have been developed (as is referred to by the Commission's Animal Welfare Strategy 2012-2015) but have yet to be adopted by the farming industry. Adoption of these systems should be supported in combination with the EIP-Agri.

Once adopted, the performance of these novel animal production systems should be evaluated in terms of animal welfare and other relevant indicators, and then comparing the outcomes with those of conventional systems. It will support farmers directly in benchmarking the performance on their farm and identifying health and welfare issues they need to address to increase farm performance. This will enable the development of saleable welfare assurance based on welfare and performance indicators. Also farms under an organic certification should fall under such types of animal welfare requirements. Existing quality labels could be used as models to study how the abovementioned animal husbandry approaches and societal approaches can match.

Further, there is a need to investigate how animal-based indicators can best be combined with resource-based indicators. Finally, the use of 'ice berg indicators' or 'sentinels' to scan large numbers of animals (e.g. at slaughter) may help to focus efforts on farms or production systems where it matters most.

Investigation into how to most effectively communicate the benefits to consumers and society to achieve the potential added value for the supply chain is an essential aspect of this effort. As such, this will also support the EU Welfare Strategy 2012-2015 on providing transparent welfare product quality to European consumers. These objectives are more likely to be achieved by engaging all the relevant stakeholders in developing innovative sustainable animal production systems.

To foster a one welfare approach amongst livestock, and (shell)fish it is recommended to implement Welfare Quality® principles in aquaculture including the '3 essentials of stockmanship' that were developed through that programme. This requires the development of protocols and systems to measure fish welfare with a set of species-specific animal-based welfare indicators, according to the approaches already in used in other livestock productions.

Priority G
Integrated farming performance

Reshaping the view of animal farming system performance by integrating environmental, health-related and societal concerns in addition to economic goal has long been touted as an aim but is far from being achieved. An overall goal is to improve the application potential of tools to improve long-term efficiency and health of animal production by promoting tailored management strategies that would go beyond the "one size fits all" approach and include animal health and welfare and the environmental footprint besides production performance and by providing end-users with tools to achieve integrated farming performance goal in differing local contexts. Addressing this challenge requires bringing together animal sciences, veterinary sciences, biological sciences (microbiology, physiology and immunology), modelling and systems research, mechanical and electronical engineering, and social sciences. In term of biology, key issues are to identify threshold conditions of animal adaptive capacity and to understand the links between individual adaptive strategies and herd performance for improving the resilience of animal farming systems. This also relates to increased natural disease resistance and improved immune competence of the animals. Understanding of animal strategies can be achieved by analysing the response of animals to, and recovery from, perturbations in a large set of conditions and by assessing short-term and long-term efficiency. Assistance of modelling is required to track and identify the key-interactions. Concerning technology, although there are increasing numbers of monitoring systems for different components of production, there are some crucial gaps notably in being able to measure production efficiency and to overcome the significant hurdles to achieve data integration due to different frequencies, precision, and reliability of measures as many of these methods and technologies are stand-alone. There is also a need to extend them toward extensive systems (e.g. grazing, outdoors poultry rearing system). A major sociological challenge associated with integrated farming performance deals with acceptance of concept, particularly where it is underpinned by technology, by livestock managers.

Strategies for improved up-take of the new techniques developed within PLF in the farming community by improved farm management tools and decision support systems need to be devised. There is also a need to develop training and awareness, which are key factors for success of reaching small and medium farmers, and their advisors. Tailored extension and dissemination activities must be arranged in focused productive areas, having as target farmers groups, cooperatives and local communities. Regional approaches are needed because of the wide variety of farm systems.

Development of integrated mitigation strategies for enteric methane is crucial both at farm scale and landscape level. The goal is to evaluate options for delivering such systems in the variety of scenarios and traditions that represent livestock production across the wide range of European cultural and physical environments. This should then be extended to establish the performance of such systems in demonstration projects.

Priority H
Agro-Ecology based livestock production systems

High animal densities create issues of manure management, which contravenes the current objective to increase the quality of water, soil and air. The dumping of pharmaceutical residues and metabolites into the environment and the spread of antibiotic resistance threaten public health and the environment. Animal production systems based on the principles of agro ecology can better cope with these challenges. Agro-Ecology aims to stimulate natural processes to reduce inputs. This involves the increased efficiency of limiting resources, limitation of wastes through the optimisation of metabolic functioning of livestock systems, the integrated management of animal health by the adaptability of animals to increase disease resistance, the preservation of biodiversity in farming systems to ensure ecosystems services and the increase resilience of the system by valuating the diversity of resources and the complementarity between animal species/breeds and preserving. The redesign and evaluation of new systems should move beyond the control paradigm where system management aims to avoid disturbances, and should fall into the robustness and resilience paradigm in order to build systems capable of handling disturbances. Proposal should be developed by a trans-disciplinary approach among animal scientists, agronomists, veterinarians, ecologists, economists, social scientists, etc. In line with the concept of 'multi-actor approach', proposals should contribute to a new approach for the whole research innovation development chain to bridge the gap between science and practice.

Agro-Ecology can help to redesign livestock production systems mainly by stimulating natural processes to reduce inputs. Surprisingly the recent developments and publications on Agro-Ecology in academic literature have largely ignored livestock systems. The redesign of animal production systems using Agro-Ecology principles will demand a whole set of innovations targeting the different components of the farm and the food chain, from farmers to consumers. Significant effort is needed to explore the cumulative impacts (and trade-offs) of combinations of individual practices in a holistic approach.

The core action points are:
- Development and evaluation of systemic frameworks that pay attention to actors values, decisions and controversies or ecosystems dynamics.
- Models to understand and forecast responses of the agro-ecosystems to changes in practices, land use and landscape, and coastal or fresh water.
- Coordination between actors and collective organisations that manage natural resources and ecological common goods.
- The inclusion of breeding.

Special attention should be given to:
- Reducing the use of purchased inputs: valorising alternative sources of feeds (by-products, novel feeds) and forage, using combinations of species (especially with legumes) to increase productivity and reduce mineral N fertilisation, optimising the management of livestock buildings (reduce energy consumption, improve animal welfare, improve the quality of air).
- Managing animal health in an integrated manner by capturing adaptive capacity of animals and minimising drug inputs: promoting natural mechanisms and stimulating practices for early acquisition of immunity and its maintenance, proposing

alternative methods of mobilising clean technologies or substances, disrupting host-pathogen cycles by altering the distribution of animals/herds in space and time.

- Promoting optimum metabolic functions of farming systems to reduce pollution: Improving C balance by reducing methane losses, increasing C storage by grasslands, reducing gas emissions in building, optimising agricultural recycling effluent through an integrated approach the manure chain, promoting natural landscapes clearance process and reducing losses to the environment through spatial organisation of crops and livestock.
- Conserving biodiversity in farming system: enhancing domestic biodiversity (diversity of species and breeds), assessing the influence of farming practices and land use patterns on biodiversity (plants, animals, micro-flora), building farmed landscapes to maximise the production of ecosystem services.
- Increasing system resilience to hazards: assessing the sensitivity of various types of livestock to climatic and economic risks, enhancing the adaptive capacities of animals (i.e. compensatory growth, management of body reserves, etc.), enhancing complementarities between livestock and crop production systems; enhancing the diversity of farming systems on the territories.
- Evaluation of new practices acceptability by farmers and society: analysing the socio-technical resistance to changes (i.e. aversion to risk), the possibility of risk sharing between the food chain actors, the coordination between actors.
- Finding the balance between the use of new breeding techniques in regard to the aforementioned challenges.

Healthy livestock and people

Secure animal health is of utmost importance for human health, animal welfare, resource efficiency and for the efficiency of production. We support the *'One Health'* approach to realise a healthy livestock sector and ensuring feed and food safety for people.

The theme covers topics concerning animal health and welfare, public health and the total food chain. Options should be pursued for developing integrated strategies for disease prevention or control and approaches for the evolution of agricultural production systems that are in tune with targets for improved consumer health and protection.
Mutual development of knowledge to improve human and animal health and wellbeing (risk assessments; diagnostics; epidemiological approaches; long-term consequences of dietary and other environmental impacts on health and welfare; zoonoses) is at the core of a 'One Health' approach with challenges at all levels of science, from discovery to implementation. This also includes the necessity to have the right infrastructures for health management, the necessity to survey and anticipate on emerging diseases and to have the right methods and means available for dealing with crisis situations.

The evolution of agricultural systems that promote holistic approaches to human (individual and social), animal and environmental health will demand multi-disciplinary and multi-stakeholder approaches. Improved understanding of ecological and epidemiological drivers of disease emergence, persistence and spread, and applications for improved disease control through integrated strategies requires transnational as well as local actions.

By minimising disease, we also improve resource efficiency so these topics add to this section (above) as well as being important in their own right. Actions under this heading could build on progress made in the DISCONTOOLS project and at the same time adhere to the EU animal health strategy 'Prevention is better than cure'.

For the 2016/2017 work programme of Horizon 2020 we recommend four main priorities to address the "Healthy livestock and people" issues:

- **I: Fortify animal disease prevention and control**
- **J: The microbiome from an integrated One-Health perspective**
- **K: Modulation of the immune system**
- **L: Vector borne diseases & European border epidemiology**
- **M: Potential functional components improving animal food product quality**

Priority I
Fortify animal disease prevention and control

The goal is to appraise the opportunities for strengthening disease prevention, control and, if applicable, eradication through combinations of system approaches and disease management strategies. To different degrees of intensity research has been done over the years on various aspects of disease control. Such work includes the development of vaccines, of biosecurity controls, of exploiting genetic diversity in resistance to disease, on the role of nutrition and management in susceptibility and/or resistance and tolerance to disease etc. Little or no effort has yet been given to evaluating the opportunities for integrating these approaches to provide broader based management strategies for disease management. The research needed is to assess whether or not combined approaches confer valuable advantages in disease management and if so, which major disease problems may be accessible to such approaches and to make recommendations on how such packages might be implemented. Major progress may be made when research from different disciplines is combined, for example microbiology, host genetics, and system development. Specific attention could be given to the development of vaccines against immunosuppressing agents, for example PRRSV and African Swine Fever. This may have broader implications for vaccine development against immunosuppressing infectious diseases in humans, like HIV.

A few crucial issues in European animal health control are mentioned below:

- Gastrointestinal health of the new-born animal is dependent on proper priming of the immune system, creating an efficient gastro-intestinal barrier and a "healthy" commensal microbiota, by applying optimised nutrition to mothers during pregnancy or egg laying period and in the first life phase of the new-born. The trans generational transfer and neonatal priming of nutrition-induced gut health, gut physiology, and immune system development and resilience provides sustainable improvement of healthy agricultural animal production systems for the future.
- New diagnostic tools are required that can be applied in herd management. Better control of disease depends, for its effective implementation, on reliable and rapid methods for the identification of disease. Inadequacies in current diagnostic methods limit the effectiveness of disease control within Member States and across borders. Continued research to develop and field test rapid, and if possible pen-side, diagnostic tools for diseases detection in livestock and fish is needed. This includes especially the development of diagnostics to enable identification of antimicrobial-resistant organism, the presence of resistance genes, and the ability to distinguish between naturally infected and vaccinated animals (DIVA approach). Specific attention is needed to assure that diagnostic information results in actions leading to better management of health and safety of man and animals.
- The on-going emergence of antimicrobial-resistance may be considered to be the single largest threat to human and animal health. It follows that research aimed at combatting antimicrobial-resistance, underpinning the development of novel antimicrobials and alternatives to antimicrobials including biological approaches (microbial antagonism, bacteriophages, bacteriocins) should take the highest priority. This also relates to increased natural disease resistance and improved immune competence of the animals. The intransigence of this problem together with its urgent need for solutions merits a very broad call for activity with a view to capturing as full a spread of novel, imaginative approaches as possible. In addition, assuming that antibiotic use remains one of the major risk factors leading to antibiotic resistance, research should be directed towards establishing antibiotic-free production systems.

- Poultry red mite (*Dermanyssus gallinae* or PRM) is a widespread, economically important ectoparasite in poultry farms worldwide, causing particularly significant problems in egg laying systems. Economic costs associated with PRM control and production losses have been estimated at €130 million per year for the EU egg industry. It is accompanied by veterinary risks (including zoonoses), and occupational health issues through allergic reactions among farm workers. Control of PRM is becoming increasingly difficult due to development of resistance to some acaricides and withdrawal of others since stricter legislation concerning active ingredients. This lack of effective control options has exacerbated the welfare issues associated with PRM –such as aggressive feather pecking and cannibalism. Development of novel and sustainable methods to control PRM is therefore needed. State-of-the-art applied technologies (including genomics, transcriptomics and vaccines), socio-economic studies and a better understanding of PRM should be combined to create the most effective methods and measures.

Priority J
The microbiome from an integrated One-Health perspective

Research to date has begun to reveal the great importance that the interaction between the human (or animal) host and the gut microbiome has on the health of the host. Through their natural complexity and the various bioactive metabolites, the microbiota harbours a full range of functionalities that represent a tremendous potential for health management, therapeutic intervention and industrial applications of biological chemistry. These functionalities could be screened by functional analyses to favour beneficial effects and limit detrimental ones. The intestinal microbiota are a key target but is not alone (respiratory or skin microbiota also play important roles). Microbiota are under the influence of external parameters some of which may be open to control (e.g.: animal genetics, weaning conditions, diet, immune competence, livestock system, environmental conditions). Such control may enable better management of overall robustness of animals and reduce the use of drugs in the livestock industry to improve public health.
Several functionalities required to be considered:

- The installation and manipulation of microbiota in neonates (prebiotic, probiotic, others) to strengthen the immune resistance of farm animals to infectious diseases and to the imprinting of the pattern of expression of xenobiotic metabolising enzymes in the gut and in the liver.
- The understanding of the barrier function against colonisation/ infection towards some pathogens (e.g.: Salmonella in poultry).
- The interaction of pathogenic and commensal bacteria, are they the same micro-organism with various faces or different strains.
- The impact of life cycle, the environmental conditions (dust/ammonia) impact on various microbiomes (gut, respiratory tract, skin) are not known.
- Human and animal pathogens might acquire antibiotic resistance from microbiota microbiome or from environmental microbiomes and therefore characterisation of the resistance reservoirs and routes of resistance exchange with pathogens and other microbial communities is crucial.
- The impact on the human population, however, also requires knowledge on what mechanisms are underlying susceptibility to such parameters and what physiological and immune biomarkers to assess in order monitor health status of the population at risk. Currently, not many biomarkers are available and there is an urgent need to improve the level of understanding.
- The potential role of probiotics to manipulate animal microbiota and as a consequence the microbiota of animal products.

Priority K
Modulation of the immune system

With the policy emphasis on developing strategies for improved health and protection from disease (both in people and in livestock) research to reveal the practical options to use the 'management' of the gut microbiota to promote host health takes a high priority. The gut and airways of agricultural animals and humans contain an elaborate and fiercely active mucosal immune system. Abnormalities and incompleteness in the regulatory capacity of this local immune system hamper development of sustainable health status and compromise production performance and welfare. Improved understanding of basic mechanisms underlying mucosal immune tolerance induction, microbiota interaction and dietary immunomodulation enhances immune competence and disease resistance in next generation animals. Modulation of the capacity and activity of the immune system through nutrition and the use of immunomodulating compounds results in innovative nutrition, husbandry, management concepts and feed interventions. More precisely, the programming, development and maintenance of a properly functioning gastrointestinal tract, with an improved resistance to pathogens and other stressors will improve the health and welfare of animals and lead to further reduction in the use of antibiotics in livestock farming and saving on the cost for animal health. The identified bio-indicators of resilience and robustness with predictive value for good animal health will result in improved feed efficiency and ecological footprint. Dietary immunomodulatory compounds and husbandry management effects will strengthen the immune system to better prepare animals for infections and, thereby, improve their resilience.

Special attention should be given to:

- Integrated gut health management includes the identification of host genetic factors underlying (early life) microbial colonisation of the gut and aspects of immune competence later in life.
- Identification of nutritional and microbial factors underlying immune competence and disease susceptibility of livestock.
- Development of rapid (*in vivo*, *ex vivo*, *in vitro*, *in sillico*) test-models to predict the effect of host (epi-)genetic, nutritional and/or microbial factors on immune competence. This includes (nutritional) intervention studies and studies to unravel underlying mechanisms of immune competence.
- Metagenomics and functional genomics approaches should be used for studies in young animals, under different environmental conditions (including unhealthy animals), to assess the impact of genetic and nutritional factors on metabolism, growth and development, infection resistance and immune markers.
- In addition, immune traits (cell subsets or molecular markers) that are heritable in different environments should be investigated and linked to enhanced production traits to investigate the underlying genetic and molecular basis for the phenotype.
- This knowledge should be used to identify genetic and nutritional factors and subsets of microbiota that promote the development of a healthy gut.
- For invertebrates reared in aquaculture and in terrestrial farms, that lack acquired immune systems, improvement in knowledge about genetic basis of immunity is needed to target better sanitary and breeding strategies.

Priority L
Vector borne diseases & European border epidemiology

Up to 70% of emerging infections are vector borne and/or zoonotic and have a major impact on livestock and wildlife. Vector borne viral diseases currently threatening European livestock include West Nile (poultry/equines), Japanese encephalitis (porcine), Rift Valley Fever (ruminants) and Bluetongue (ruminants). These viruses are biologically transmitted between animals by hematophagous arthropod vectors (mosquitoes, biting midges, sandflies and ticks). Understanding why some pathogen-vector interactions are 'successful' and others are not, is key in assessing the risks of the establishment and spread of vector borne diseases in Europe. The importance of the challenge for public health requires addressing it at the international level with cutting edge technologies that remain to be developed and implemented. An integrated approach is needed to prepare Europe for these vector borne diseases along three main lines: vector biology (surveillance, vector competence, control), pathogenesis (natural challenge animal models) and vaccination strategies. Additional actions are needed to control vector borne diseases. Recent climate change data indicate increasing arthropod-borne transmission rates in temperate climate zones and increased transmission intensity in warmer climates. This may have a larger impact on epizootic diseases and zoonotic disease than foreseen, indicating the need for improved infectious disease surveillance and innovative control strategies for vector borne diseases.

Besides focussing on vector borne diseases, additional actions are needed to improve insights in the epidemiology of infectious animal disease(s) (including notifiable diseases and those, with zoonotic potential) at the European borders. Reliable data of infectious disease epidemiology in border areas are indispensable to develop effective control strategies and prevent introductions of such diseases in the European Union. The challenges are to encompass all the research needed to provide risk management with measures reducing the risk of introducing infectious (contagious and vector borne) diseases in the EU territories. Southern and eastern borders of the EU are the main concern. This requires broadening the scope refining the surveillance strategies towards known pathogens, developing breakthrough technologies that allow surveillance of unknown pathogens (high throughput sequencing plus data mining) and to combine several kinds of surveillance strategies (targeted monitoring, syndromic or participative surveillance). The topic will provide data regarding circulating microbiomes in livestock and wild animals on a wide scale. Besides epidemiological studies and data collection, improvement of modelling strategies and methodologies, human sciences are required to analyse the cost effectiveness of management measures. This can be used to evaluate the human aspects of managing an emerging threat, the social acceptability of control measures (such as culling), monitoring of risk factors for introducing an exotic disease which can be associated to trading practices.

Also the diffusion of antibiotics resistance genes hosted by bacteria is fully relevant in terms of "European border epidemiology". The challenges are to encompass all researches needed to provide risk manager with measures susceptible of reducing the risk of introducing infectious (contagious and vector borne) diseases in the EU territories.

Another challenge is to interfere in the "kingdom hopping" of microorganisms of concern for plant health and animal health, including zoonotic agents, in order to monitor and control their introduction or spread. This requires early detection

diagnostic tools. In recent years, most of the research efforts have been put in the development of high throughput, generic, quick and cheap methods. A number of these methods have been validated intra-laboratory or through limited ring trials. To foster the use of these methods beyond research laboratories, additional work needs to be performed to further test the methods, fully validate them and where appropriate compare these methods to reference methods. In some cases further harmonisation, including (CEN, ISO) standardisation is needed and reference materials need to be developed. In addition generic diagnostic/detection methods should be assessed for adaptation to a broader use.

Priority M
Potential functional components improving animal food product quality

Assessment of potential functional components improving animal food product quality that may reduce the risk of lifestyle diseases is limited.. There should be focus on the growing the understanding of the role of nutritional compounds at the molecular level i.e., their interaction with genes, and their subsequent effect on metabolism. This knowledge should allow the rational design of strategies to manipulate body/cell functions through diet; that goal is expected to have an extraordinary impact on animal products, livestock health and human health as well. There is still a lack of knowledge about the interaction between genetic background (genotype) and environmental factors (diet). Thus, attention should be directed towards nutrigenomics aspects, aiming to investigate the influence of diet components on gene expression profiles and metabole status. In particular this could be achieved by the study of ways (how and when), during the life of the animal or its parents, to establish specific epigenetics marks favourable for a better food production.

To achieve this goal the modern wide scale techniques of molecular biology including transcriptomic, proteomic, and metabolomics have to be applied. This allows for examination of comprehensive relationships between environment, including feed components and genotype of animals. Attention also should be given to development and assessment of biomarkers that could be useful for food quality determination and safety as well as prediction of suitable properties for technological processing. Moreover, the evaluation of influence of functional characteristics of various bioactive components for supplementation in feed on the microbiota in the digestive tract in relation to animal host should also be taken into account. Specific genotypic requirements for feed diet additives including microbial population and its impact on bioactive components of animal products should be determined.

Healthier foods and novel dietary based immunotherapy approaches can play a crucial role in preventing infections and diseases and here we contribute to how specific dietary components can modulate the immune system. Immunomodulation by food refers to the consequences of exposure to dietary components steering the immunological defence system in a preferred manner. Chronic inflammation, including that of the gut and triggered by nutritional factors, can lead to extensive non-specific damage, showing that inflammation and immune dysfunction are intimately tied. Selected dietary proteins (and oligopeptides derived thereof), fatty acids and carbohydrates have a distinct regulating effect on the expression of a variety of genes involved in inflammatory pathways and immunity, explaining their therapeutic activity. Even newly defined plant-derived extracts could exert such activities. These dietary components can thus actively alter immune reactivity or tolerance inducing capacity by enhancing or inhibiting specific immune responses.